UM10692

SSL2109ADB1105 - 120 V/18 W PAR38 high PF isolated LED driver demo board

Rev. 1 — 9 April 2013 **User manual**

Document information

Info	Content
Keywords	SSL2109ADB1105, flyback converter, high PF, PAR38
Abstract	This document describes the operation of a 120 V/18 W non-dimmable LED driver demo board featuring SSL2109A and using an isolated flyback topology. The SSL2109ADB1105 demo board is designed for both PAR38 and PAR30 form factors used in Solid State Lighting (SSL) applications

Revision history

Rev	Date	Description
v.1	20130409	first issue

WARNING

Lethal voltage and fire ignition hazard

The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

1. Introduction

This user manual describes the operation of the SSL2109ADB1105 demo board featuring the SSL LED driver SSL2109A in a 120 V/18 W isolated application.

The SSL2109ADB1105 demo board is designed for driving a 10-LED string load.

The PCB dimensions are compatible with both PAR38 and PAR30 form factors used in SSL applications.

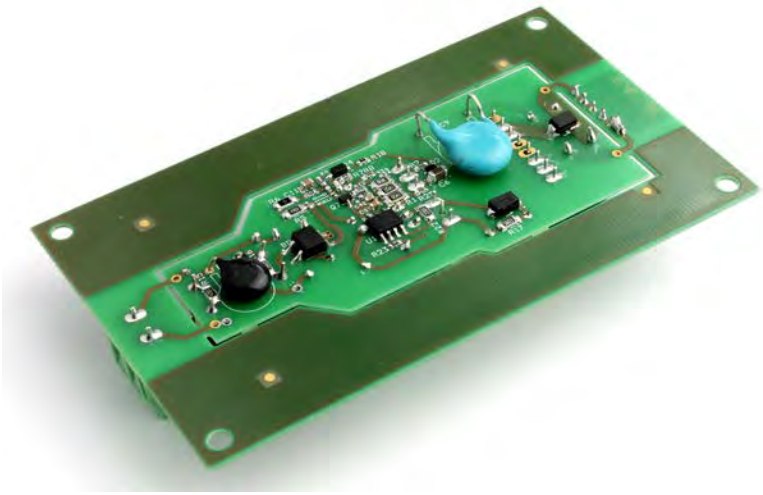
The demo board provides a simple and effective solution having high power factor, low THD and high efficiency for SSL applications.

1.1 Features of the application

- PAR38 and PAR30 form factor compatibility
- Open LED and short circuit LED string protection
- OverCurrent protection (OCP) and OverTemperature protection (OTP)
- Power factor (PF) greater than 0.9 and THD < 20 %
- Efficiency greater than 85 %
- Minimal changes required in design for a 230 V/18 W SSL application
- Compliant with IEC61000-3-2 harmonics standard
- Compliant with FCC15 EMC standard

The assembled top and bottom board views are shown in Fig 1 with the board dimensions in Fig 3. The board dimensions allow enough headroom with either PAR38 or PAR30 lamps.

a. Top view

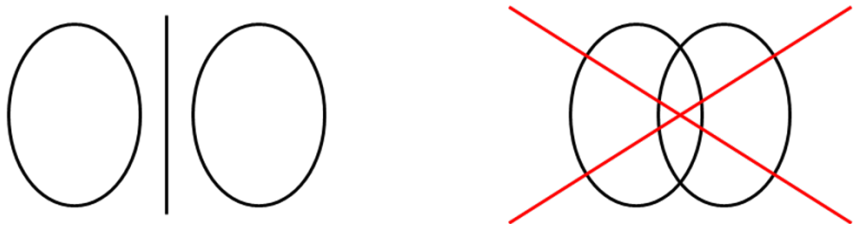


b. Bottom view

Fig 1. SSL2109ADB1105 120 V/18 W PAR38 demo board

2. Safety

The board must be connected to mains voltage. Avoid touching the demo board while it is connected to the mains voltage. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Galvanic isolation of the mains phase using a variable transformer is always recommended.



a. Isolated

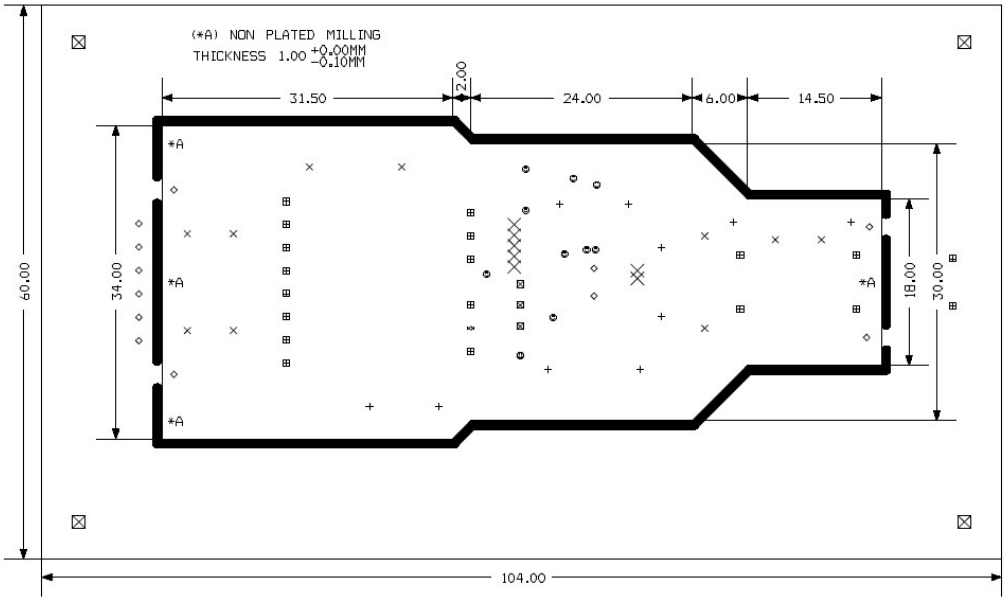
b. Not isolated

Fig 2. Variable transformer isolation symbols

3. Specifications

Table 1. Specifications of the SSL2109ADB1105

Symbol	Parameter	Value
V_{mains}	AC mains supply voltage	120 V; ±10 %
P_{in}	input power	17.6 W at nominal V_{mains} = 120 V
P_{out}	output power	15.4 W
V_{LED}	output voltage (LED voltage)	25 V to 40 V with nominal V_{LED} = 35 V
I_{LED}	output current (LED current)	455 mA
I_{ripple}	output ripple current	130 mA (p-p)
$\Delta I_{LED}/ \Delta V_{mains}$	line regulation	1.9 mA/V (±5 % I_{LED} at ±10 % V_{mains} variation)
$\Delta I_{LED}/ \Delta V_{LED}$	load regulation	2 mA/V (±1.65 % I_{LED} at ±10 % V_{LED} variation)
η	efficiency	88 %
PF	power factor	0.98
THD	total harmonic distortion	15 %
f_{sw}	switching frequency	70 kHz



DRILL CHART				
SYM	DIAM	TOL	QTY	NOTE
⊕	0.300 mm		10	
╳	0.500 mm		7	
×	0.800 mm		10	
+	0.900 mm		10	
◇	1.000 mm		12	
⊠	1.200 mm		3	
⊞	1.300 mm		19	
⊞	1.300 mm		1	NON-PLATED
☒	3.500 mm		4	NON-PLATED
TOTAL			76	

Fig 3. SSL2109ADB1105 demo board dimensions

4. Functional description

4.1 Input filtering

Common-mode and differential mode π filters are implemented to reduce common-mode or differential mode noise originating from the high-frequency (HF) switching currents/voltages in the primary of the converter from returning to the mains. This noise must be kept to a minimum by:

- Small primary current loop (C2 to pin 1 of T1, pin 3 of T1 to drain of external MOSFET Q5, ground return from sense resistors R1, R24, R26 to C2 ground)
- Snubber components D3, R17, C8 closely parallel to pins 1 and 3 of T1
- Track length from pin 3 of T1 to drain of external MOSFET to be small in order to reduce capacitance to surroundings

For this 18 W application, C2 must be chosen sufficiently large to act as a buffer for the HF current flowing in the primary but also small enough to maintain a high PF where a value of 330 nF for C2 is a good compromise.

4.2 PF adjustment

The divider network consisting of R5, R6, R7, R9, R10, D4, C10 and C11 modulates the base of Q7 according to the rectified mains. Consequently, a modulating current set by R11 flows through R8 and the sense current through R1, R24 and R26 is also modulated. Depending on the divider resistor values, the HF current through the primary has a current with a rectified mains modulation resulting in a high PF.

The PF can be increased/decreased by decreasing/increasing R5 and R6 and a compromise can be reached between PF and line regulation.

4.3 RCD clamp

Leakage inductance of the transformer is in series with primary inductance and the drain of MOSFET Q5. This leakage inductance together with the parasitic capacitance across the drain source of Q5 causes HF ringing when Q5 switches off. If the leakage is not minimized the voltage at the drain reaches high voltages levels which can damage Q5 if voltage levels exceed the maximum allowable level.

An RCD clamp (R17, C8 and D3) prevents the voltage on the drain of Q5 exceeding the maximum drain voltage when Q5 switches off.

4.4 Supply voltage

The supply voltage of the SSL2109A is achieved using an auxiliary winding. As further advantages, the auxiliary winding provides, via a resistor R25 on its underwinding, both a simple solution for improved load regulation using R12 and open-circuit protection (OCP) via the NTC pin using R13.

4.4.1 Open circuit protection

If no LED string is connected to the converter output, the voltage can quickly exceed the maximum rating of the output capacitors C3 and C7.

The underwinding of the auxiliary is connected to resistor R25 to prevent this. The voltage across R25 decreases as the output voltage increases. Consequently, the voltage at the NTC pin decreases once the current through R13 exceeds the internal current of the NTC pin. When the NTC voltage drops below 0.35 V then the SSL2109A

switches off.

An external 18 V Zener diode is included at the VCC pin to prevent that the voltage exceeds 20 V at the VCC pin for this no LED string situation

4.4.2 Short circuit

When the LED terminals are shorted, the SSL2109A defaults to its maximum demagnetization time of 36 µs. This prevents that the transformer current ramps up to an excessively large value while the input power is limited and the SSL2109A enters OPS protection (latched) mode.

Remark:

Do not try to short-circuit the LED output while the circuit is powered or without discharging C3. The short-circuit protection is intended for zero-hour short circuit protection (so a short circuit during first assembly before power is applied).

5. Demo board connections

The SSL2109ADB1105 demo board is supplied with a 120 V, 60 Hz mains supply where the board connection is shown in Fig 4.

Table 2. Input and output connections

Connector	Function	Remark
L	AC MainsL	line wire solder connection on small board
N	AC MainsN	neutral wire solder connection on small board
+	LED anode	positive LED wire solder connection on small board
-	LED cathode	negative LED wire solder connection on small board
X5	AC mains input	AC mains in terminal block
X6	LED load output	LED connector 6-way female for NXP LED load

Remarks:

Make all connections with the input mains supply switched off.

Use a protective shield over application and never touch the board when measuring or testing.

Connections and testing:

- Connect a 10-LED string load to the SSL2109ADB1105 together with power meters at both inputs and outputs.
- Connect V_{mains} (120 V (AC)/60 Hz) using an isolating transformer (initially set to 0 V) to the input connection points of the flyback converter. Alternatively, use an AC power supply with limited output current capability (for example 200 mA).
- Increase V_{mains} to 120 V (AC) and measure the different parameters as shown in Table 3.

Table 3. Input / output parameters SSL2109ADB1105

V_{mains} (V)	I_{in} (mA)	PF	P_{in} (W)	V_{LED} (V)	I_{LED} (mA)	P_{out} (W)	η
120	149	0.98	17.6	34	455	15.4	0.88

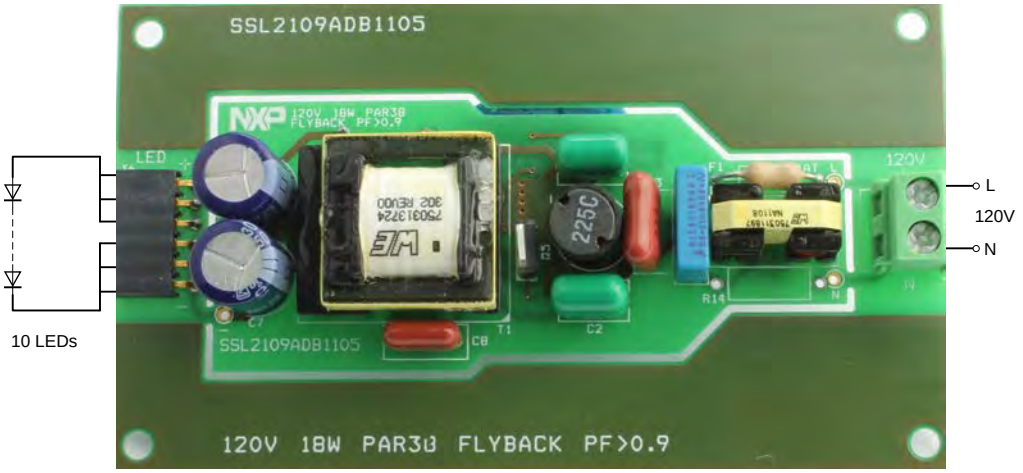


Fig 4. Board connection for SSL2109ADB1105 with 10-string LED load

6. Performance data SSL2109ADB1105

6.1 Efficiency

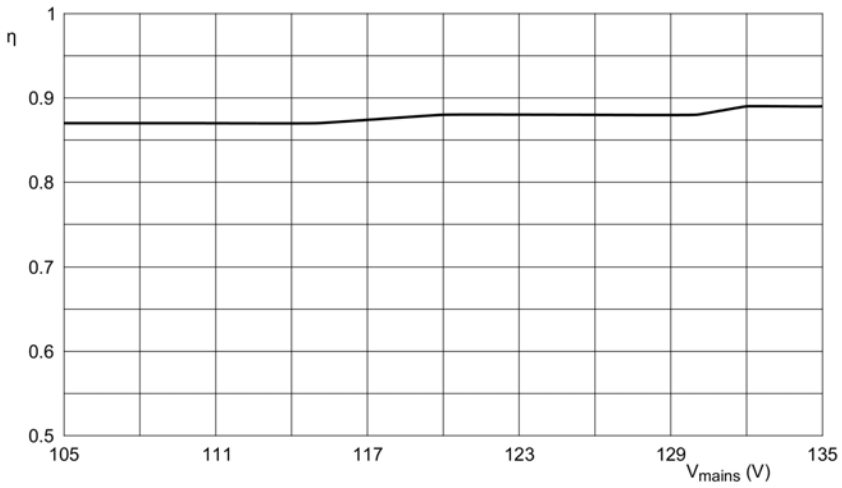


Fig 5. Efficiency as a function of mains voltage

6.2 Power factor

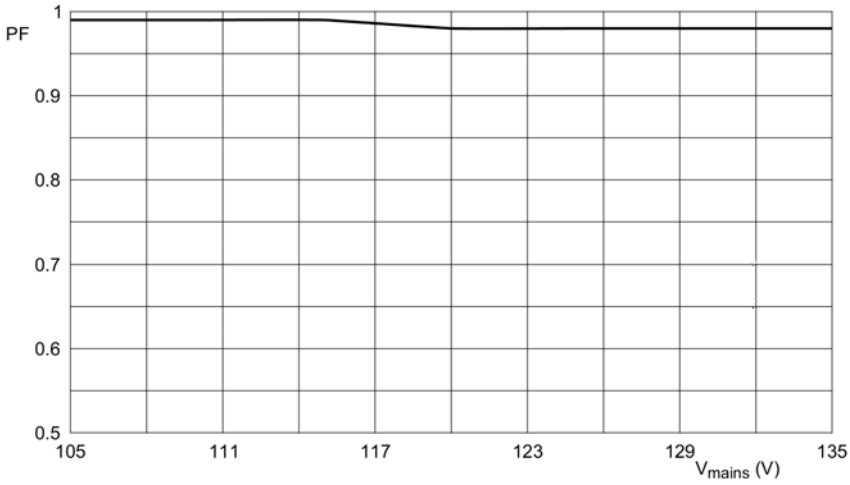


Fig 6. Power factor as a function of mains voltage

6.3 Line regulation

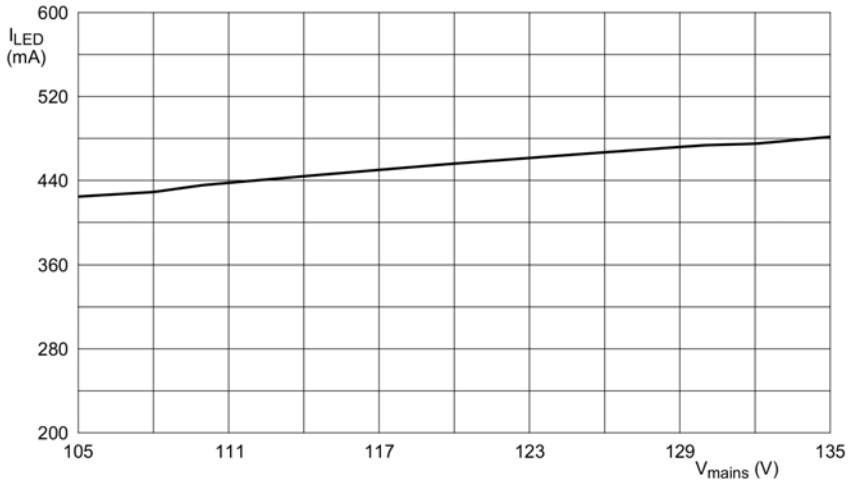


Fig 7. Line regulation

6.4 Load regulation

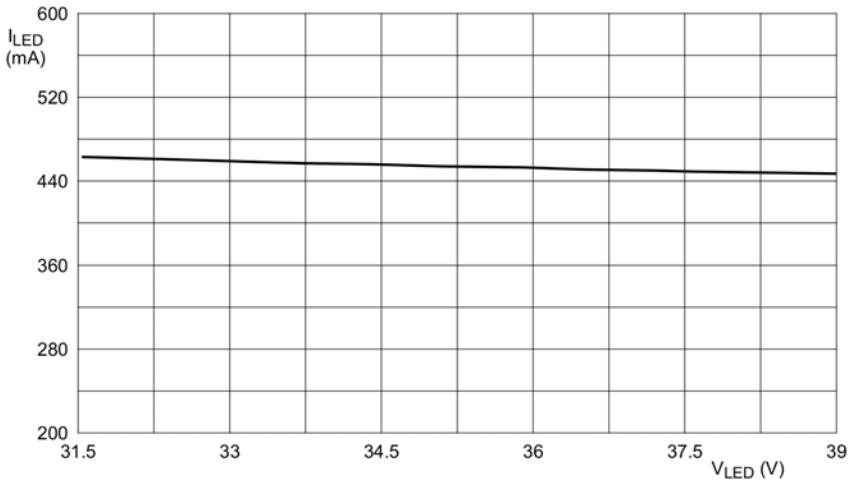


Fig 8. Load regulation

6.5 ElectroMagnetic Interference (EMI)

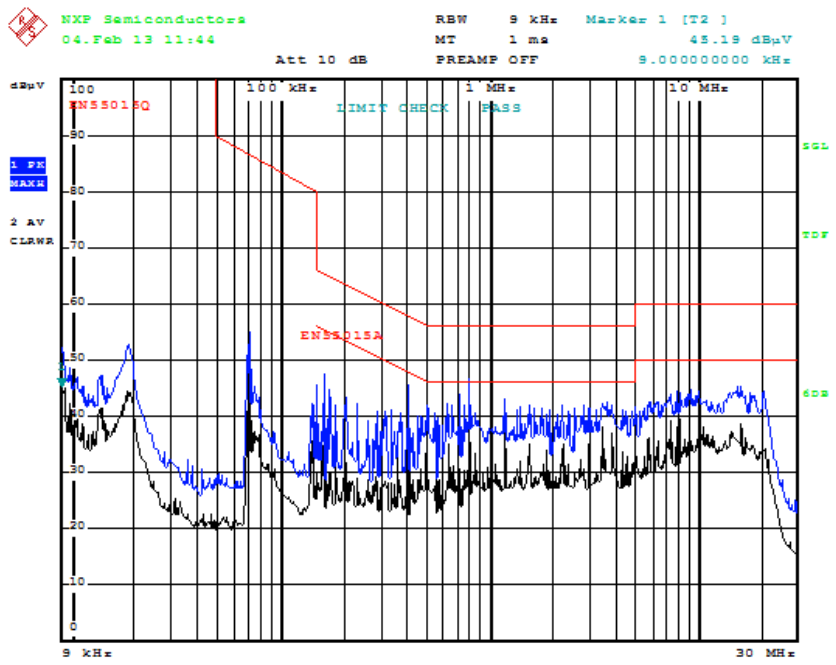


Fig 9. EMI performance

7. Schematic diagram

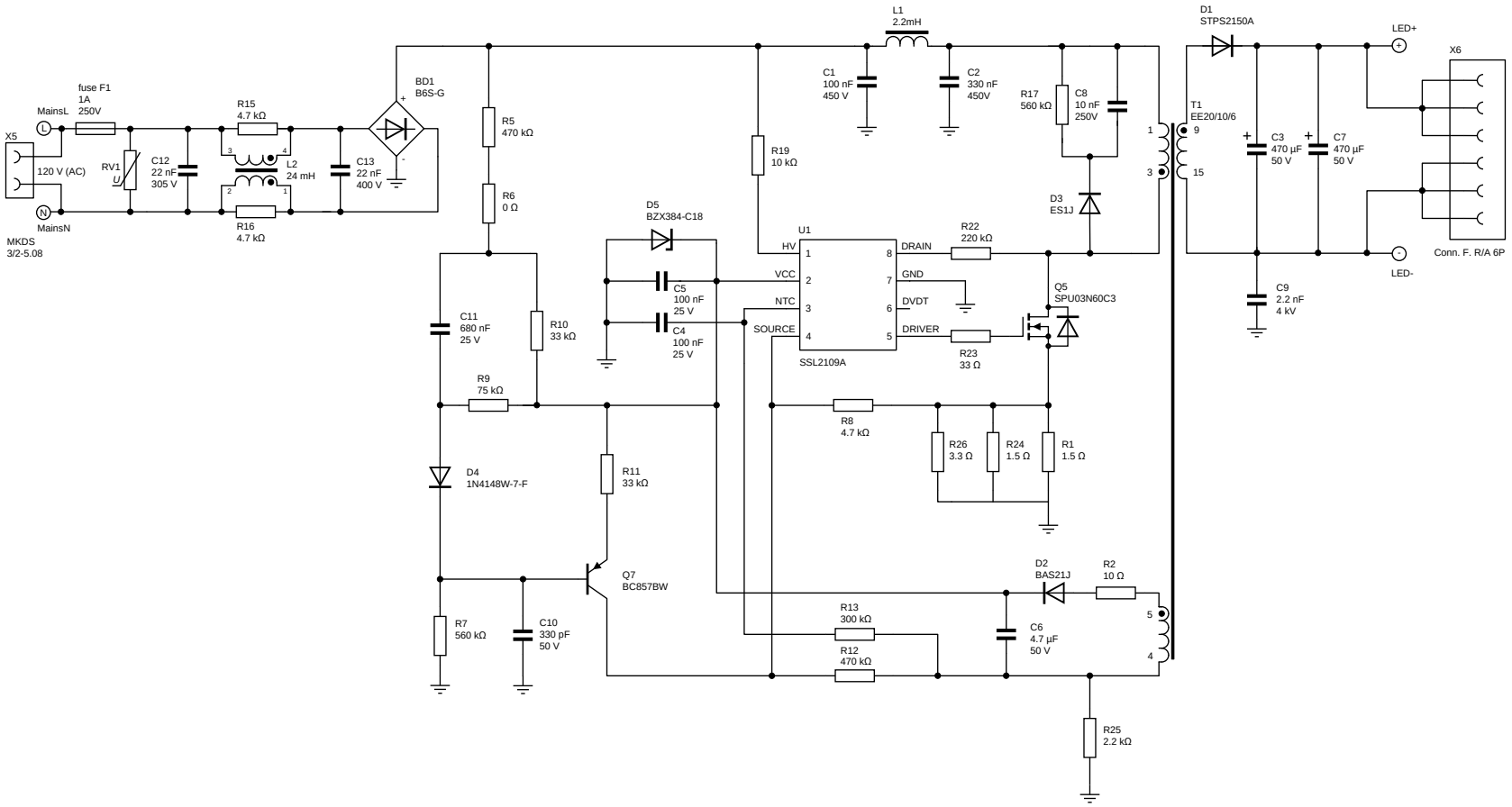
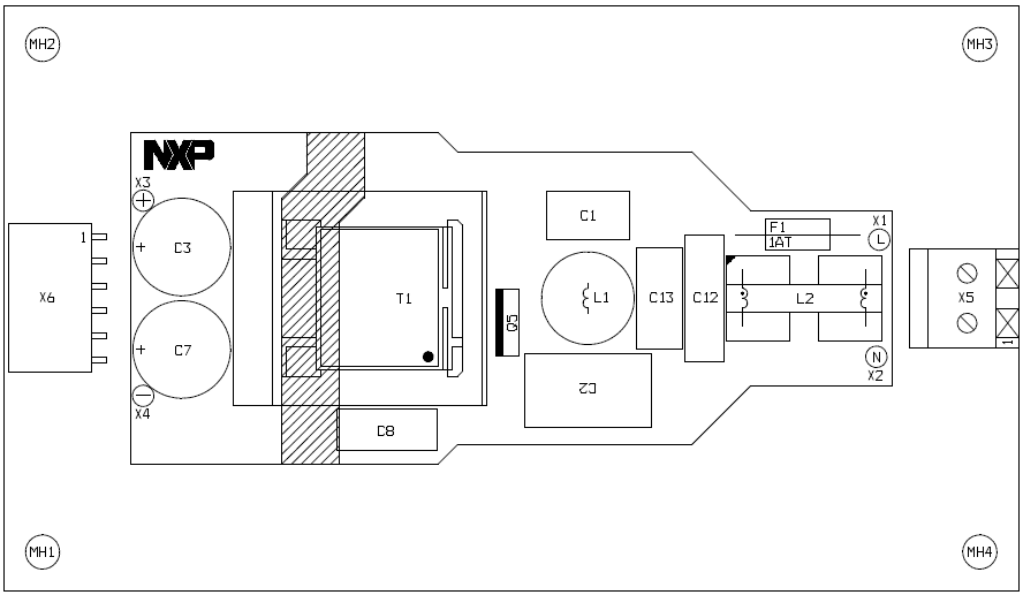


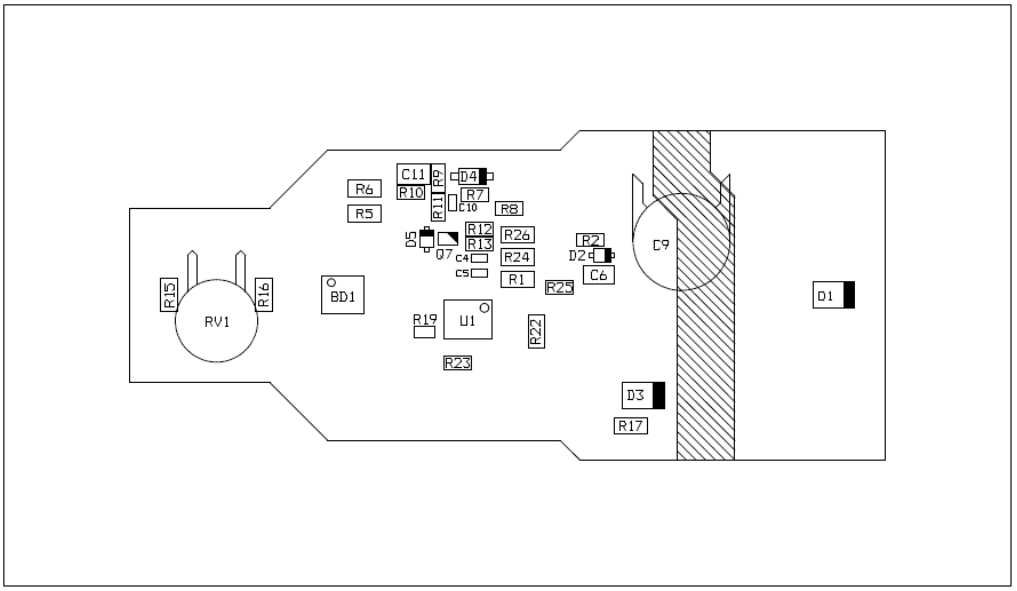
Fig 10. SSL2109ADB1105 schematic

8. PCB component assembly and layout

8.1 PCB component assembly



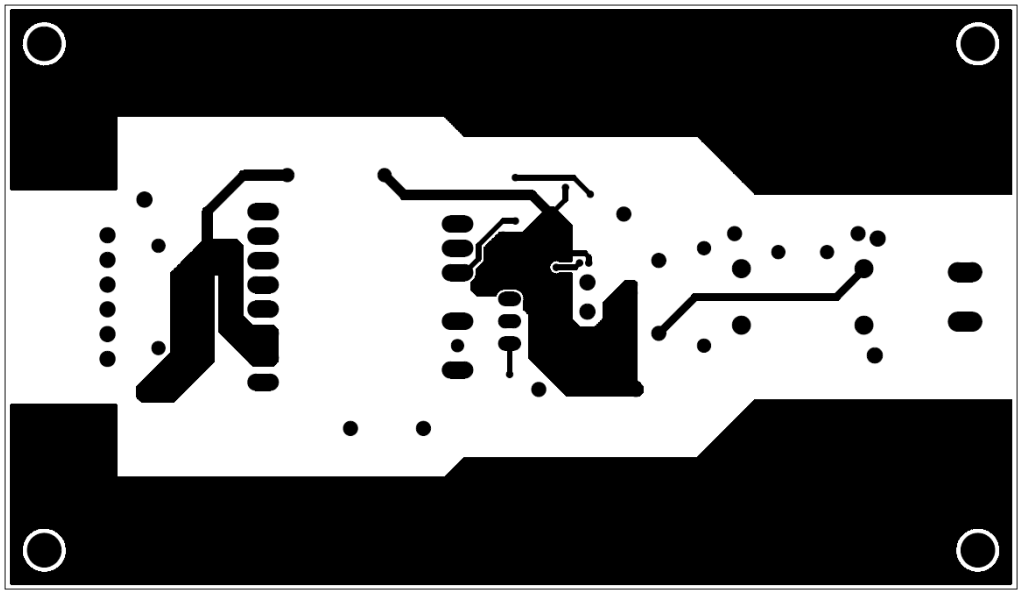
a. Top assembly



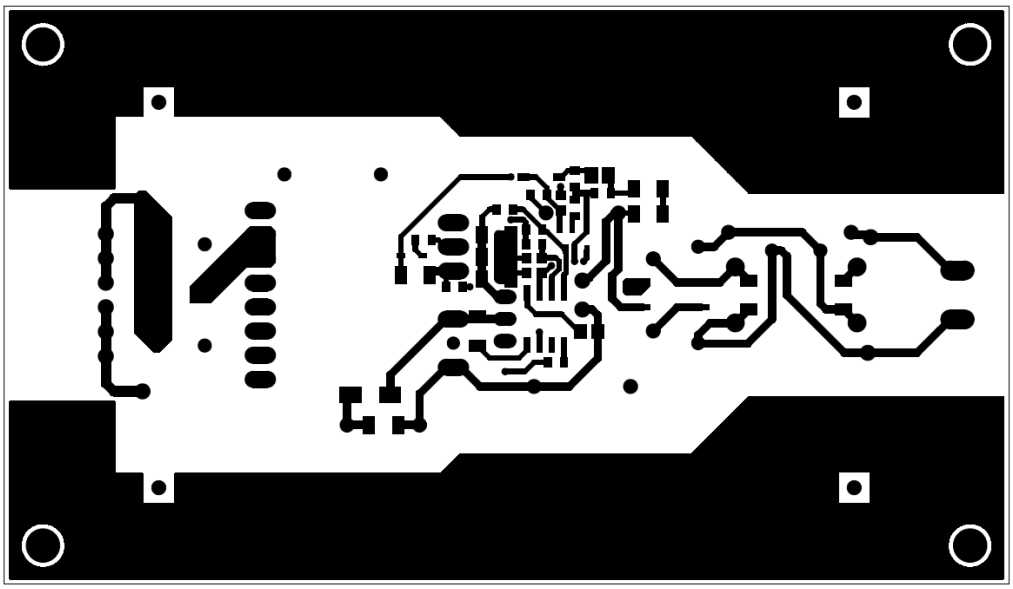
b. Bottom assembly

Fig 11. PCB component assembly

8.2 PCB layout



a. Component side



b. Solder side

Fig 12. PCB layout

9. Bill Of Material (BOM) SSL2109ADB1105

Table 4.

Reference	Description and values	Part number	Manufacturer
BD1	bridge rectifier; 600 V; 0.8 A	B6S-G	Comchip Technology
C1	capacitor; 100 nF; 450 V; 10 %; metal film; radial	CL21-450V-0.1u F/K	Guang Da
C2	capacitor; 330 nF; 450 V ; 5 %; metal film; radial	ECW-F2W334JAQ	Panasonic
C3	capacitor; 470 µF; 50 V; 20 %; electrolytic; radial	ECA1HM471	Panasonic
C4	capacitor; 100 nF; 25 V; 10 %; X7R ceramic; 0603	GRM188R71E104KA01D	Murata
C5	capacitor; 100 nF; 25 V; 10 %; X7R ceramic; 0603	GRM188R71E104KA01D	Murata
C6	capacitor; 4.7 µF; 50 V; 10 %; 1206	UMK316AB7475KL-T	Taiyo Yuden
C3	capacitor; 470 µF; 50 V; 20 %; electrolytic; radial	ECA1HM471	Panasonic
C8	capacitor; 10 nF; 250 V; 20%; polyester; radial	ECQE2103JF	Panasonic
C9	capacitor; 2.2 nF; 4 kV; 20 %; radial	DE1E3KX222MA5B	Murata
C10	capacitor; 330 pF; 50 V; 20 %; X7R ceramic; 0603	CC0603KRX7R9BB331	Yageo
C11	capacitor; 680 nF; 25 V; 10 %; 0805	C0805C684K3NACTU	Kemet
C12	capacitor; 22 nF; 305 V (AC); radial	B32921C3223M	Epcos
C13	capacitor; 22 nF; 400 V; 5 %; radial	ECQE4223JF	Panasonic
D1	Schottky diode; 150 V, 2 A; DO-214AC; SMA	STPS2150A	ST
D2	switching diode; BAS21J; 300 V; 0.25 A; SOD323F	BAS21J	NXP Semiconductors
D3	fast diode; ES1J; 600 V; 1 A; DO-214AC; SMA	ES1J	Fairchild
D4	high-speed diode; 100 V; 0.4 W; SOD123	1N4148W-7-F	Diodes Inc
D5	Zener diode; 18 V; 200 mA; SOD323F	BZX384-C18	NXP
F1	fuse slow; 1 A; 250 V	MCPMP 1A 250 V	Multicomp
L1	inductor; 2.2 mH; 240 mA; 4.5 Ω; radial	13R225C	Murata
L2	inductor; 24 mH ; common-mode choke; 250 mA; 6.3 Ω	750311897	Würth
L	solder pin for MainsL	-	-
N	solder pin for MainsN	-	-
Q5	transistor; N channel MOSFET; 650 V; 1.4 Ω	SPU03N60C3	Infineon
Q7	transistor; BC857BW; PNP; SOT323	BC857BW	NXP Semiconductors
R1	resistor; 1.5 Ω; 0.25 W; 1 %; 1206	RC1206FR-071R5L	Yageo
R2	resistor; 10 Ω; 0.1 W; 5 %; 1206	ERJ3GEYJ100V	Panasonic
R5	resistor; 470 kΩ; 0.25 W; 5 %; 1206	RC1206JR-07470KL	Yageo
R6	resistor; 0 Ω; 0.25 W; 5 %; 1206	RC1206JR-070RL	Yageo
R7	resistor; 560 kΩ; 0.1 W; 1 %; 0603	CRCW0603560KFKEA	Vishay
R8	resistor; 4.7 kΩ; 0.1 W; 1 %; 0603	CRCW06034K70FKEA	Vishay
R9	resistor; 75 kΩ, 0.1 W; 1 %; 0603	CRCW060375K0FKEA	Vishay
R10	resistor; 33 kΩ; 0.1 W; 1 %; 0603	CRCW060333K0FKEA	Vishay
R11	resistor; 33 kΩ; 0.1 W; 1 %; 0603	CRCW060333K0FKEA	Vishay
R12	resistor; 470 kΩ; 0.1 W; 1 %; 0603	CRCW0603470KFKEA	Vishay
R13	resistor; 300 kΩ; 0.1 W; 1 %; 0603	CRCW0603300KFKEA	Vishay
R15	resistor; 4.7 kΩ; 0.25 W; 5 %; 1206	RC1206JR-074K7L	Yageo
R16	resistor; 4.7 kΩ; 0.25 W; 5 %; 1206	RC1206JR-074K7L	Yageo

Reference	Description and values	Part number	Manufacturer
R17	resistor; 560 kΩ; 0.25 W; 5 %; 1206	RC1206JR-07560KL	Yageo
R19	resistor; 10 kΩ; 0.125 W; 5 %; 0805	CRCW080510K0FKEA	Vishay
R22	resistor; 220 kΩ; 0.25 W; 5 %; 1206	RC1206JR-07220KL	Yageo
R23	resistor; 33 Ω; 0.1 W; 5 %; 0603	RC0603JR-0733RL	Yageo
R24	resistor; 1.5 Ω; 0.25 W; 1 %; 1206	RC1206FR-071R5L	Yageo
R25	resistor; 2.2 kΩ; 0.1 W; 5 %; 0603	ERJ2GEJ222X	Panasonic
R26	resistor; 3.3 Ω; 0.33 W; 1 %; 1206	ERJ8BQF3R3V	Panasonic
RV1	varistor; 300 V (AC); 42 J; radial	ERZV07D471	Panasonic
T1	flyback transformer ; EE20/10/6 (EF20)	750313724 Rev00	Würth
U1	IC; SSL2109A; SO8	SSL2109A	NXP Semiconductors
X5	mains connector terminal block	MKDSN2,5-5.08	Phoenix Contact
X6	LED connector terminal block	BL3.36Z	Fischer Elektronik
X6	LED connector terminal block (alternative)	SSW-106-02-G-S-RA	Samtec
+	solder pin for LED+	-	-
-	solder pin for LED-	-	-

10. Transformer specification

An EE20/10/6 (EF20) is used

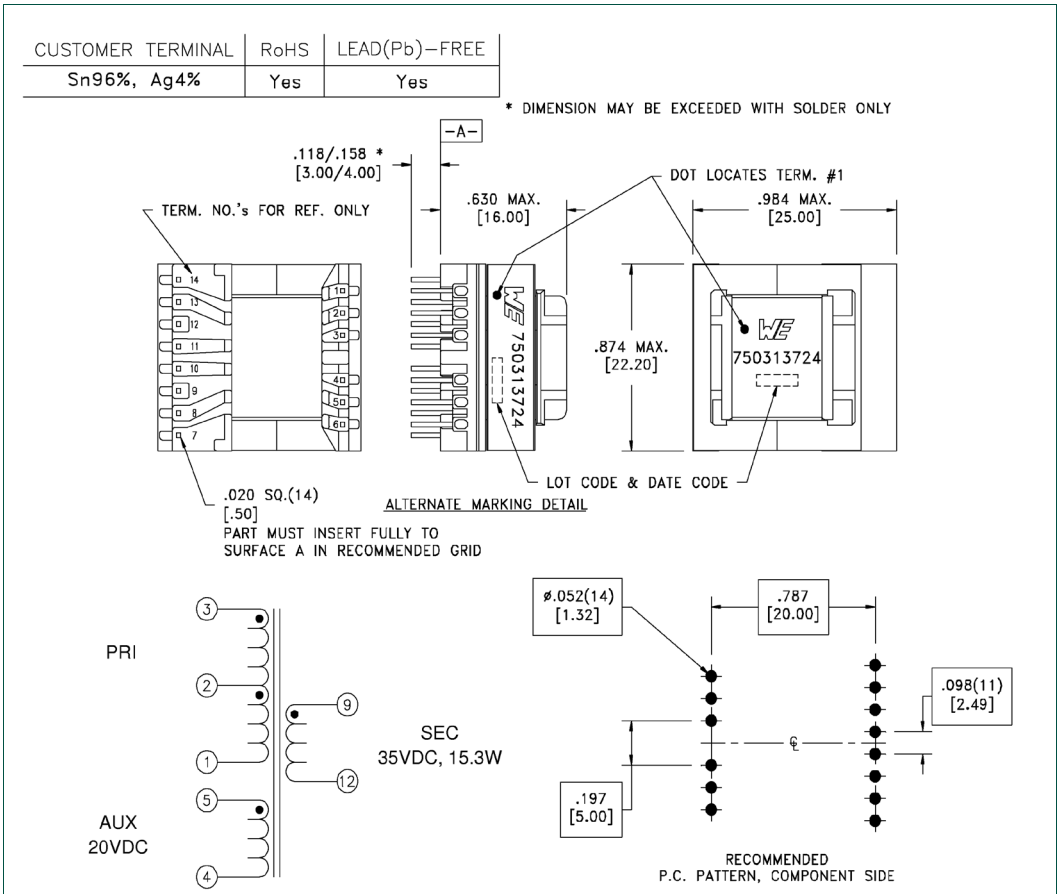


Fig 13. Transformer schematic T1

Table 5. Electrical specification

All values are specified at 25 °C unless otherwise specified. All values without tolerance are typical values. Reinforced insulation for a primary circuit at a working voltage of 150 V (RMS)

Parameter	Value	Comment
DCR (3-1)	1.2 Ω; ±10 %	
DCR (5-4)	242 mΩ; ±10 %	
DCR (9-12)	165 mΩ; ±10 %	
primary Inductance (3-1)	800 µH; ±10 %	100 mV; 10 kHz
leakage Inductance (3-1)	maximum 12 µH	100 mV; 100 kHz Short 5-4 and 9-12
primary saturation current	975 mA	
turns ratio (3-1):(9-12)	3:1; ±2 %	
turns ratio (3-1):(5-4)	4.5:1; ±2 %	

11. Derivative board 230 V/18 W PAR38 with PF > 0.9 and η > 85%

To realize a 230 V/18 W PAR38 derivative board from the 120 V/18 W PAR38 demo board with PF > 0.9 and η > 85 % the following changes have to be implemented as shown in Table 6.

Table 6. Changes required for derivative board

Part reference	Description	Remark
C13	capacitor; 22 nF; 630 V; 5 %; radial	voltage rating change from 400 V to 630 V
D11	TVS diode; 400 V; DO-41	add BZW04-342 between rectifier output and ground
R1	resistor; 4.7 Ω; 0.25 W; 1 %; 1206	value change from 1.5 Ω to 4.7 Ω
R6	resistor; 470 kΩ; 0.25 W; 5 %; 1206	value change from 0 Ω to 470 kΩ
R24	resistor; 3.9 Ω; 0.25 W; 1 %; 1206	value change from 1.5 Ω to 3.9 Ω
R26	resistor; 1.3 Ω; 0.25 W; 1 %; 1210	value change from 3.3 Ω to 1.3 Ω
RV1	varistor; 300 V (AC); 42 J; radial	delete
T1	flyback transformer; EE20/10/6 (EF20)	change Würth 750313724 Rev00 to Würth 750313930 Rev00

Table 7 includes a summary of performance data for the derivative board.

Table 7. Performance data for derivative board

Symbol	Parameter	Value
V_{mains}	AC mains supply voltage	230 V; ±10 %
P_{in}	input power	18 W at nominal V_{mains} = 230 V
P_{out}	output power	16 W
V_{LED}	output voltage (LED voltage)	25 V to 40 V with nominal V_{LED} = 35 V
I_{LED}	output current (LED current)	470 mA
I_{ripple}	output ripple current	130 mA (p-p)
$\Delta I_{LED}/\Delta V_{mains}$	line regulation	±3.4 % I_{LED} @ ±10 % V_{mains} variation
$\Delta I_{LED}/\Delta V_{LED}$	load regulation	±0.25 % I_{LED} @ ±10 % V_{LED} variation
η	efficiency	89 %
PF	power factor	0.95
THD	total harmonic distortion	18 %
f_{sw}	switching frequency	75 kHz

11.1 Transformer specification

An EE20/10/6 (EF20) is used

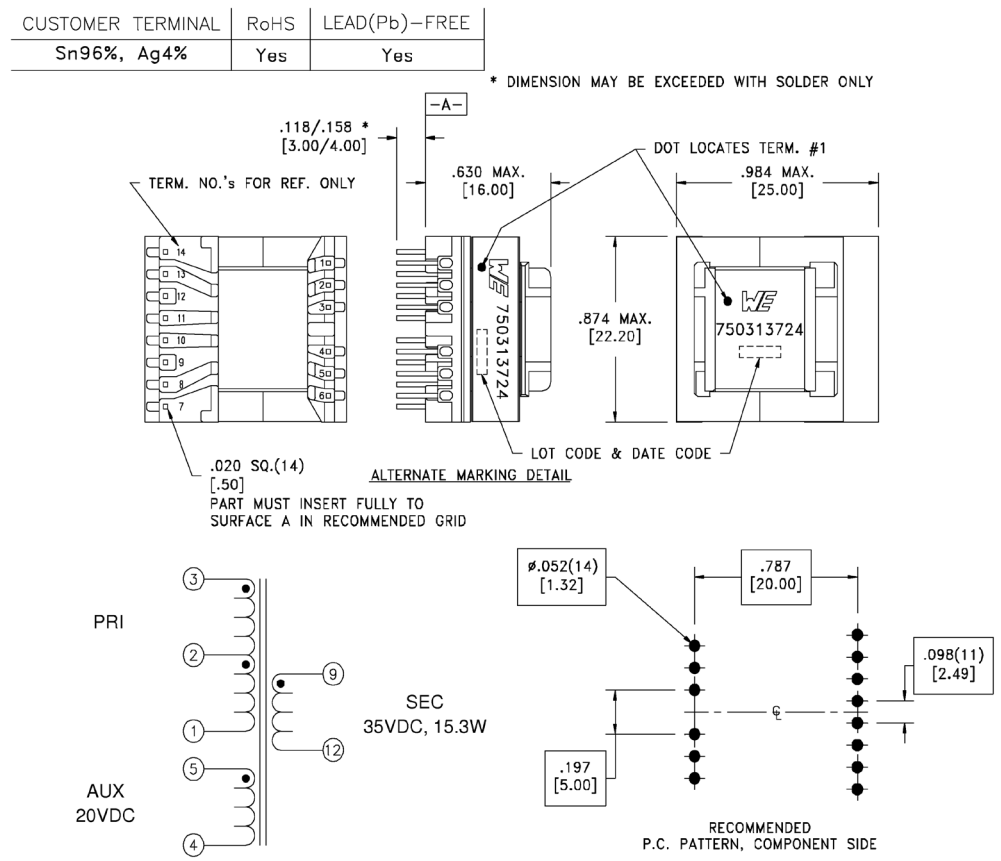


Fig 14. Transformer schematic T1 for 230V derivative

Table 8. Electrical specification

All values are specified at 25 °C unless otherwise specified. All values without tolerance are typical values. Reinforced insulation for a primary circuit at a working voltage of 250 V (RMS)

Parameter	Value	Comment
DCR (3-1)	2.6 Ω; ±10 %	
DCR (5-4)	520 mΩ; ±10 %	
DCR (9-12)	440 mΩ; ±10 %	
primary Inductance (3-1)	1.2 mH; ±10 %	100 mV; 10 kHz
leakage Inductance (3-1)	maximum 30 µH	100 mV; 100 kHz Short 5-4 and 9-12
primary saturation current	1.3 A	
turns ratio (3-1):(9-12)	3:1; ±2 %	
turns ratio (3-1):(5-4)	4.5:1; ±2 %	

11.2 Schematic diagram

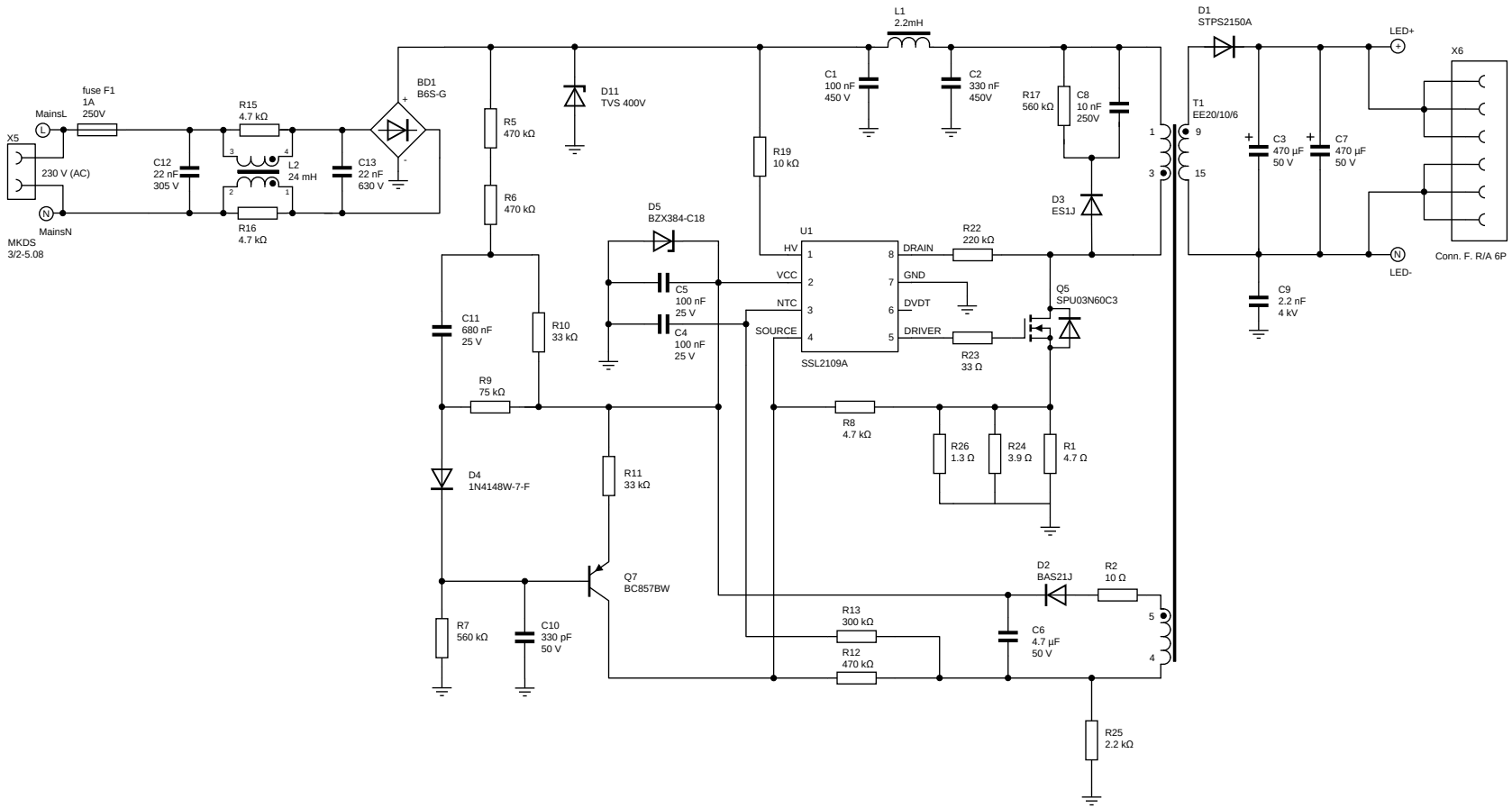


Fig 15. Schematic of 230 V/18 W PAR38 derivative board having PF > 0.9 and η > 85 %

12. Derivative board 230 V/18 W PAR38 PF = 0.7 and η > 85%

To realize a 230 V/18 W PAR38 derivative board from the 120 V/18 W PAR38 demo board with PF = 0.7 and η > 85 % the following changes have to be implemented as shown in Table 9.

Table 9. Changes required for derivative board

Part Reference	Description	Remark
R1	resistor; 4.7 Ω; 0.25 W; 1 %; 1206	value change from 1.5 Ω to 4.7 Ω
R3	resistor; 390 Ω; 2 W; radial	add
R4	resistor; 390 Ω; 2 W; radial	add
R5	resistor; 470 kΩ; 0.25 W; 5 %; 1206	delete
R6	resistor; 0 Ω; 0.25 W; 5 %; 1206	delete
R7	resistor; 560 kΩ; 0.1 W; 1 %; 0603	delete
R9	resistor; 75 kΩ, 0.1 W; 1 %; 0603	delete
R10	resistor; 33 kΩ; 0.1 W; 1 %; 0603	delete
R11	resistor; 33 kΩ; 0.1 W; 1 %; 0603	delete
R24	resistor; 3.9 Ω; 0.25 W; 1 %; 1206	value change from 1.5 Ω to 3.9 Ω
R26	resistor; 3.9 Ω; 0.25 W; 1 %; 1206	value change from 3.3 Ω to 3.9 Ω
RV1	varistor; 300 V (AC); 42 J; radial	delete
C3	capacitor; 100 µF; 50 V; 20 %; electrolytic; radial	value change from 470 µF to 100 µF
C7	capacitor; 100 µF; 50 V; 20 %; electrolytic; radial	value change from 470 µF to 100 µF
C10	capacitor; 330 pF; 50 V; 20 %; 0603	delete
C11	capacitor; 680 nF; 25 V; 10 %; 0805	delete
C13	capacitor; 22 nF; 630 V; 5 %; radial	voltage rating change from 400 V to 630 V
C14	capacitor; 3.3 µF; 400 V; 20 %; electrolytic; radial	add
C15	capacitor; 100 nF; 400 V; 1210	add
D4	high-speed diode; 100 V; 0.4 W; SOD123	delete
D11	TVS diode; 400V; DO-4	add BZW04-342 between rectifier output and ground
D16	S1JL high-voltage diode; 600 V; 1.5 A; DO-219-AB; SMF	add
Q7	transistor; BC857BW PNP; SOT323	delete
T1	flyback transformer; EE20/10/6 (EF20)	change Würth 750313724 Rev00 to Würth 750313930 Rev00

12.1 Transformer specification

Transformer specification is given in Section 11.1.

Table 10 includes a summary of performance data for the derivative board.

Table 10. Performance data for derivative board

Symbol	Parameter	Value
V_{mains}	AC mains supply voltage	230 V; ±10 %
P_{in}	input power	18 W at nominal V_{mains} = 230 V
P_{out}	output power	15 W
V_{LED}	output voltage (LED voltage)	25 V to 40 V with nominal V_{LED} = 35 V
I_{LED}	output current (LED current)	445 mA
I_{ripple}	output ripple current	50 mA (p-p)
$\Delta I_{LED}/\Delta V_{mains}$	line regulation	±4.5 % I_{LED} at ±10 % V_{mains} variation
$\Delta I_{LED}/\Delta V_{LED}$	load regulation	±1.6 % I_{LED} at ±10 % V_{LED} variation
η	efficiency	83 %
PF	power factor	0.7
f_{sw}	switching frequency	100 kHz

12.2 Schematic diagram

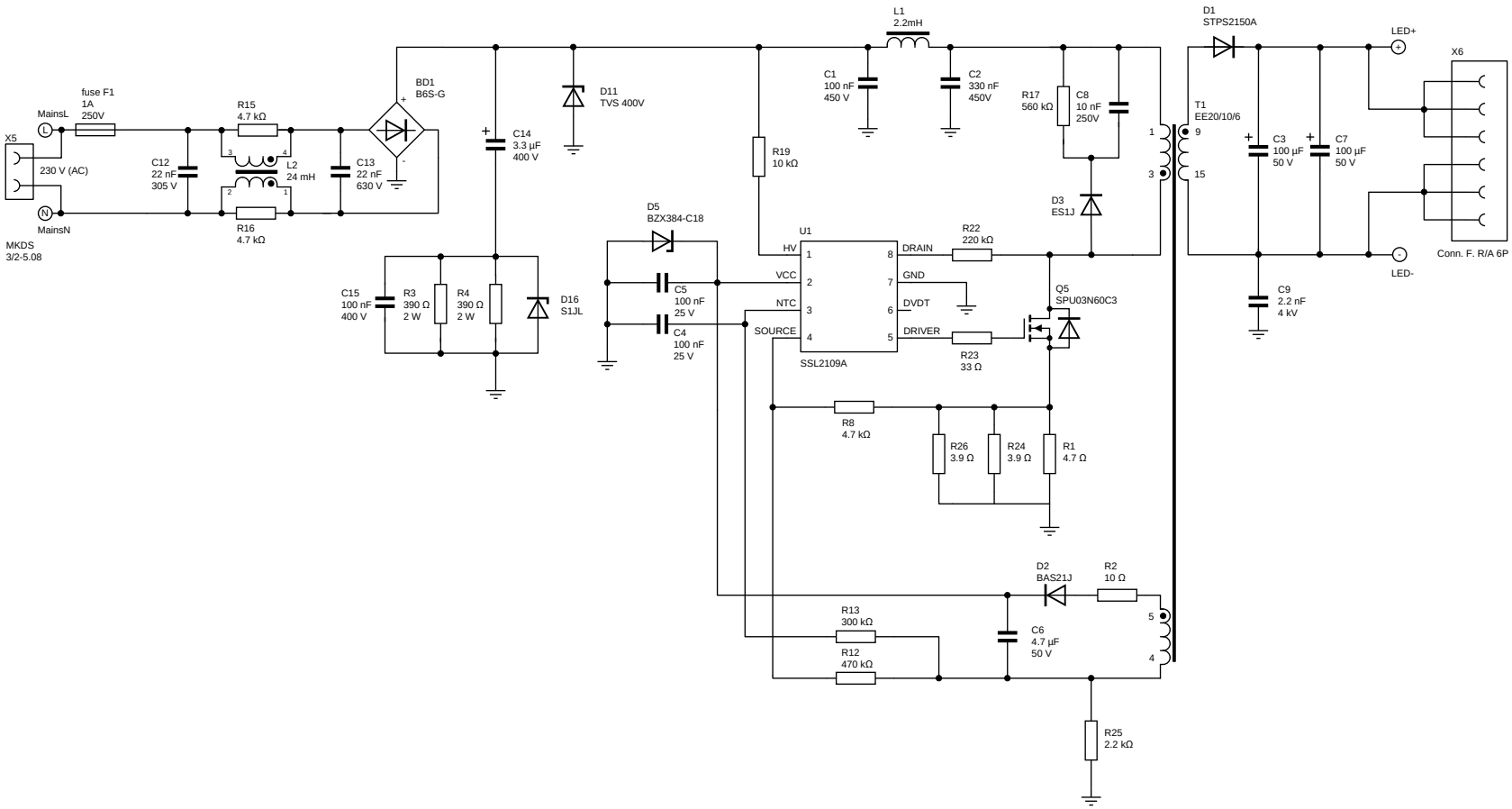


Fig 16. Schematic of 230 V/18 W PAR38 derivative board having PF = 0.7 and η = 83 %

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Date of release: 9 April 2013
Document identifier: UM10692